Damage analysis of spot replacement sleepers interspersed in ballasted railway tracks

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29th Nordic Seminar on Computational Mechanics
NSCM-29
R. Larsson (Ed.)
2016

DAMAGE ANALYSIS OF SPOT REPLACEMENT SLEEPERS INTERSPERSED IN BALLASTED RAILWAY TRACKS

NSCM-29

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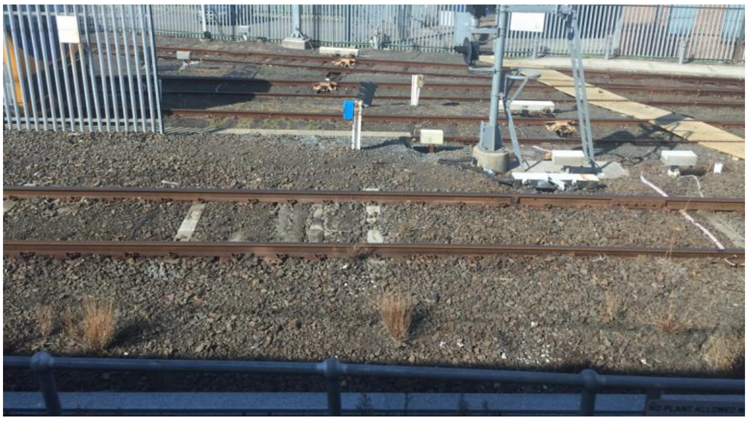
Key words: Damage analysis, ballasted railway track, interspersed track, spot replacement sleeper, railway sleeper.

Summary. The interspersed pattern sleeper, a spot replacement of old timber sleeper with concrete or composite counterparts, of railway track is often used as a temporary maintenance for secondary railway lines such as yards, balloon loops or siding. However, their negative effect on the railway has not been taken into account. It is observed that performance of interspersed tracks can quickly deteriorate after some years. On this ground, a nonlinear simulation of interspersed sleeper railway is conducted using the finite element program, STRAND7, so that the structural damage analysis can be conducted. Two moving point loads representing an axle load along each rail has been established to investigate the worst-case, potential actions for premature damage of sleepers and differential settlement of the track. Dynamic displacement and acceleration of sleeper are then evaluated by varying the speed of the moving force from 5 km/h to 120 km/h and the interspersed patterns to identify the causes of track deterioration and track differential settlement. The insight strongly demonstrates the potential cases and engineering guideline for interspersed railway tracks.

1 INTRODUCTION

In many parts of railway networks around the world, timber has been used as a sleeper for a railway track over time. As the timber sleeper life span is around 15-20 years depending on application and maintenance, such timber sleepers will be required for maintenance or even a huge replacement at certain point in time. Also, unless used in low speed operation, timber sleepers require a strengthening for enhancement in ability to withstand high velocity operations or to restrain longitudinal rail forces preventing a track buckling. “Interspersed” is a method that can be used as a measure against these problems. Interspersed railway track can be built by re-sleepering old and rotten timber sleepers and replace it with concrete sleepers [1]. Due to differential track stiffness, deterioration process, and operational parameter, many patterns of interspersed railway tracks have been introduced i.e. 1 in 2, 1 in 3, 1 in 4 and so on (which mean there is 1 concrete sleeper in every indicated number of sleeper such as 1 in 4 mean 1 concrete sleeper in every 4 sleepers including the concrete itself). It is important to note that this type of railway track mainly existed in a third class track with low operational speeds. The key reason is that this type of track has various flaws derived from how it is built. The replacement of old timber sleepers is frequently done over old and soft existed formation, which has been in services for so long, by installing new stiff concrete sleepers in its existing place. This can result in soil foundation failure, track stiffness inconsistency (as it made up of both concrete and timber sleepers), and different decay rate [2]. These can impair the long-term performance of interspersed railway tracks as shown in Figure 1. Figure 1 shows the conditions of interspersed railway tracks in low-speed operation (<25 km/h). The tracks have been commissioned between 2006 and 2008 and have served as a link to maintenance junctions. The photos were taken in April 2016 during a site visit.


(TOP)


(BOTTOM)

Figure 1: Deteriorated interspersed railway track (Top: mud pumping, and Bottom: ballast pulverisation and ballast dilation)

The serviceability limit state has become the governing criteria for sleepers made of different material properties in the existing aged track systems. This method is sometimes called ‘spot replacement’ or ‘intersperse method’. It is important to note that a general recommendation (e.g. by Australian Office of Transport Safety Investigations) is to perform concrete sleeper installation only 'in-face' (i.e. the practice of installing the same sleeper type constinuously rather than interspersed with other sleepers in between, also referred to as 'on-face') [3-4]. This paper aims at investigating the damage potentials of the interspersed railway tracks. Based on critical literature review, this research has never been presented in open literature [3-6]. The insight into this practice will help rail track engineers to enable truly predictive maintenance and improve reliability of infrastructure assets.

2 NONLINEAR FINITE ELEMENT MODELLING

A 2D Timoshenko beam is selected as a beam model because it was found to be one of the most suitable options for modelling concrete sleeper [5]. For both rail track and sleeper they were designed as a beam element in finite model so shear and flexural deformation can be included in computation [6]. The rail pads at the rail seat are simulated by using series of spring dash-pot elements. In order to replicate ballast supports, non-linear tensionless beam support is used. The tensionless support can correctly demonstrate ballast under the sleeper as this attribute allow beam to lift over the support while the tensile support is omitted [6]. For train on the rail track, it is simplified to 2 points loads with 100kN in magnitude, 2m apart, on each side of the rail track (4 point loads in total), to enable envelop analysis (maximum responses). Figure 2 shows the illustration of the model. The numerical simulation is conducted using non-linear transient dynamic solver in Strand7 to enable tensionless capability of ballast. The nonlinear iteration (Newton Raphson) has been used to compute the ballast contact and support. The model has been validated earlier using experimental parameters, field data and previous laboratory results [7-8].

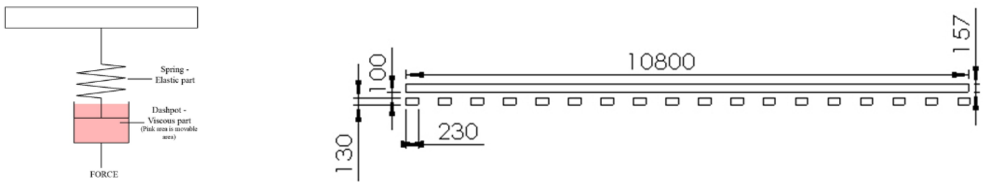


Figure 2: Schemetics of interspersed railway track modelling

3 DYNAMIC MOVING LOAD ANALYSIS

The effects of train velocity on the maximum responses of sleepers can be seen in Figure 3. The train speeds from 5 to 120 km/h have been investigated. It is clear than the timber track has higher deformation. At rail seat, the relative uplifts of the sleepers tend to cause deteriorations of railway tracks over time.

4 CONCLUSIONS

- Spot replacement or interspersed tracks can deteriorate relatively faster than open-face tracks (i.e. pure concrete or timber sleepers). This is also evidenced by field monitoring.
- The cause of rapid deterioration such as track mud pumping, ballast pulverisation and ballast dilation is due to relative dynamic uplift responses of sleepers.
- Ballast dilation can be aggravated by concrete sleeper vibrations at resonance.

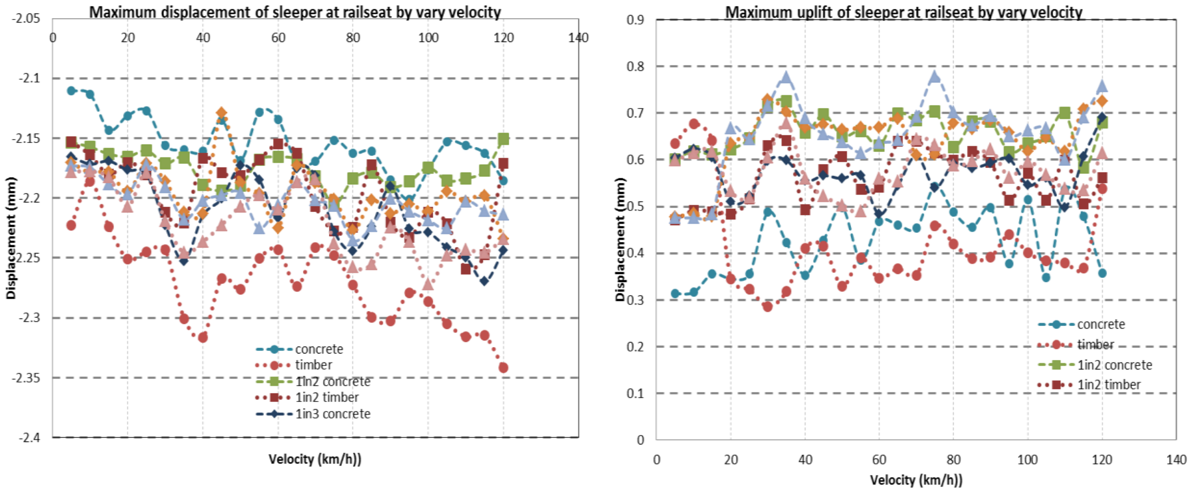


Figure 3: Dynamic responses of sleepers in the interspersed tracks

ACKNOWLEDGEMENT

Financial support from Japan Society for the Promotion of Science (JSPS) via Grant No. JSPS-L15701, BRIDGE Grant (Collaboration between University of Birmingham and University of Illinois at Urbana Champaign), and European Commission for H2020-MSCA-RISE Project No. 691135 “RISEN: Rail Infrastructure Systems Engineering Network” is gratefully acknowledged.

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